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THE COMPUTER AND THE ARCHITECTURAL PROFESSION.

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DESCRIPTORS- *ARCHITECTURAL EDUCATION, *BUILDING DESIGN, *COMPUTERS, *GRAPHIC ARTS, *INFORMATION PROCESSING, CITY PLANNING, COMMUNICATIONS, CONSTRUCTION COSTS, ENGINEERING, OFFICE MANAGEMENT, PROGRAMING, SCHOOL SITE, TECHNOLOGY,

THE ROLE OF ADVANCING TECHNOLOGY IN THE FIELD OF ARCHITECTURE IS DISCUSSED IN THIS REPORT. PROBLEMS IN COMMUNICATION AND THE DESIGN PROCESS ARE IDENTIFIED. ADVANTAGES AND DISADVANTAGES OF COMPUTERS ARE MENTIONED IN RELATION TO MAN AND MACHINE INTERACTION. PRESENT AND FUTURE IMPLICATIONS OF COMPUTER USAGE ARE IDENTIFIED AND DISCUSSED WITH RESPECT TO--(1) PROGRAMING, (2) SITE ANALYSIS, (3) BUILDING DESIGN, (4) CIVIL AND STRUCTURAL DESIGN, (5) ENVIRONMENT AND EQUIPMENT, (6) CITY AND REGIONAL PLANNING, AND (7) OFFICE AND JOB MANAGEMENT. DEMANDS ON COMPUTER TECHNOLOGY AND THE ARCHITECTURAL PROFESSION ARE INDICATED. A TECHNICAL SUPPLEMENT ON COMPUTER TECHNOLOGY IS INCLUDED ON--(1) COMPUTER PROGRAMING, (2) HARDWARE, (3) THE COMPUTER, (4) NON-COMPUTER METHODS, AND (5) A GLOSSARY OF TERMS RELATED TO COMPUTER TECHNOLOGY. (MM)

the computer and the architectural profession

CENTER FOR ARCHITECTURAL RESEARCH
SCHOOL OF ARCHITECTURE RENSSELAER POLYTECHNIC INSTITUTE

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This is the first in an anticipated series of reports to be issued by the Center For Architectural Research and dealing with the results of graduate-research projects.

The Center has three established objectives -- service to the architectural profession and the building industry, enrichment of architectural education, and problem-solving for specific sponsors. Certainly this report is designed to be of service to the architectural profession, and using the medium of research, to contribute to the education of potential practicioners. We trust it will be successful on both counts.

In addition to his graduate studies, David Haviland is a full-time member of the research staff at Rensselaer. We feel that his contributions to our research program, and his particular area of interest in graduate studies, reflect a worthy combination of research and education -- and a stimulating combination of subjects -- the computer and architecture.

Alan C. Green, Director
Center for Architectural Research
June, 1966

by DAVID S. HAVILAND

the computer and the architectural profession

contents

1 / communication

Communication is at the very heart of architecture. In fact, the two are inseparable. As the planning and design of a building -- or of a city -- evolves, it is communication which holds the process together.

No matter how large or small the problem, the process is the same. Requirements and local conditions are brought together with ways of solving them in the architect's mind. Ideas and concepts result, and eventually a design solution is evolved. Finally, this solution is translated into a physical reality of some sort; the process is complete.

At every point along the way, many people, opinions, and groups of factual data are brought to bear on the problem. Needs must be defined by the client and clarified by the architect. A host of past experiences -- some personal and others communicated by words or pictures -- are considered. Functional systems must be investigated; materials, processes, and structural factors must be considered, weighed, and accepted or rejected as needed. Costs must be kept in mind, codes must be checked, feasibilities must be determined, and all the parts must finally be brought together into a coherent whole. As a last step, this whole must be transmitted to those who will supply labor and materials to build it. A failure in any part of the process will mean failure in the entire process. Much is at stake.

No wonder an architect, when finally confronted by the finished product, feels a deep sense

financial and real estate interests

owner

occupants & tenants

building committee

site

location of site

local, neighborhood and regional characteristics

background research work on similar facility types and the philosophy behind their solution

PRELIMINARY ANALYSIS

client

programmers

professors and long-time "heros"

developers of special processes, etc.

friends and collegaues

other architects and past solutions

magazine writers

architectural program or list of requirements

past approaches

special analyses of function

general philosophy and outlook

background and training

education

new methods and materials

planning standards

SCHEMATIC DESIGN

draftsmen

engineers and consultants

specification writers

manufacturers and materials men

contractor

estimator

inspectors and enforcement agencies

costs

codes and regulations

materials and construction practices

environment

structure

performance standards

furnishings, equipt.

PHYSICAL SOLUTION

of pride. When he thinks of the complexity of the process that produced it, a feeling of accomplishment and triumph is only natural.

But below the surface of his pleasure there is a layer of frustration -- frustration caused by the very complexity of the process. Pride of commission is offset by fear of omission; triumph is qualified by the certain knowledge that the next problem will bring the same complexity, and more frustration. The architect asks: how could the job have been better done? how could he have considered a wider range of possibilities in design? how could he have better communicated his thoughts and ideas to his draftsmen, his spec writers, and his builders? how could he have alleviated some of the frustrations of bringing people, ideas and solutions together?

He does not necessarily ask how the process could have been made simpler -- he knows that it is intrinsically complex -- he only wishes there were better ways, or tools, of coordinating it, of bringing order to it.

To complicate matters, he knows that the frustrations will increase as more kinds of people become involved in architecture, as new facility types are evolved, as more information becomes available, and as new methods and materials come onto the market.

Historically, many tools of coordination and

communication have been presented. Materials classification, design guidelines, standard details, checklists, and mechanized office procedures have been proposed -- and used -- by the profession at large. In the 1960s, however, a new tool has been presented, a tool which has huge potential: the "black box" technology of modern communications and computer systems.

This is not a tool to end all tools; there are no panaceas. But it is an important tool. The huge potential involved is no less than that of completely reshaping the practice of architecture and planning.

So the question of the computer and the technology which it represents cannot be considered lightly. The architecture profession must take a look -- a long, hard look -- at the computer, at its advantages and limitations, at its relation to the men who use it, and at its place in architecture and planning.

2 / man + machine

In any momentous technological development, sudden and of great scale, two extreme camps of thought are bound to crop up right away. The development of the electronic computer is no exception.

On the one side there are the "machine-firsters": the machine is the answer to all problems, and has the ability to replace the man that created it. At the other extreme are the "man-firsters": the machine is evil, it is not in the 'tradition of man', and it should not be given the chance to replace him.

Of course, both arguments are absurd. And yet they come up continually when even intelligent men sit down to talk about the computer and the architectural profession. Why? Above and beyond the emotional overtones, there is a more basic reason: simple ignorance. Before it is possible to even begin assessing the "place" of the computer in architecture and planning, there must be an attempt to understand the machine, to appreciate its advantages, and to learn of its limitations.

What <u>is</u> the black box? Here are a few clues:

- In essence, the computer is, and always has been, a kind of super calculating machine. It began as an improvement over the desk calculator; it added, subtracted, multiplied and divided many times faster than the desk machine. The real innovation, though, was that the computer was given a MEMORY: it could be instructed to "store" a set of complex instructions (a program) for solving a problem. The electronic computer can also "store" results of calculations, recalling them later when necessary.

- The computer's prime stock in trade is SPEED. The reason it can undertake difficult tasks (say, solving twenty simultaneous equations), is not that it does them any differently than man (somebody had to tell the machine how to do it), but that it takes so little time on one individual operation that millions of these operations together do not take a great deal of time.

- The computer's second great advantage is PATIENCE. It can be instructed to perform an operation, or even a long string of operations, over and over again.

- There have been many technological developments on the basic calculating computer. New ways of feeding in information and instructions, new ways of manipulating information, and larger memory units have been developed, all but eclipsing the magnificence of the original invention.

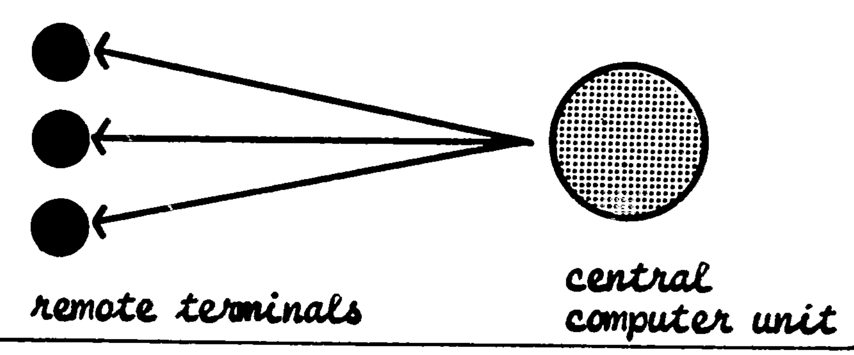
- An electronic computer is, above all, an invention of man. While it can lead him in directions he would not have the patience to pursue, and while it can "solve" problems more exactly than he ever could, the computer cannot, strictly speaking, do anything that its inventor cannot do -- given infinite time and patience.

From the standpoint of the architect, three later developments in the area of computers and computer technology are, or someday will be, particularly significant:

- The development of self-correcting, or heuristic routines, have great implications for any field that is not based in pure mathematics. Through their use, the computer can use information generated within itself to modify its position. It can work problems on a "trial-and-error" basis, rather than on a pure yes-or-no basis.

- The development of graphic means of communicating with the machine is particularly important to architects. The further development of graphic consoles and light pens will allow him to communicate directly, and in a language he understands.

- The development of time-sharing will allow operators at many remote stations to simultaneously communicate with the machine in a central location. This will eliminate the need for a large machine in every office.



The computer has some great limitations, too:

- Despite some capacity for self-correction, it cannot "learn" in the accepted sense. While computer terms, such as brain, memory, and nerve center, are handy tags for visualizing what is going on, they should not be confused with the "real thing".

- Although the machine can uncover new paths, or lead thought in new directions through pure patience in listing new combinations, it does not produce ideas in the traditional sense of that word. It does not enjoy moments of inspiration, and it does not recognize the "Eureka, I have it!"

- While the machine in its operation can reorganize data along any predetermined format, it looks to man for subjective evaluation of that data.

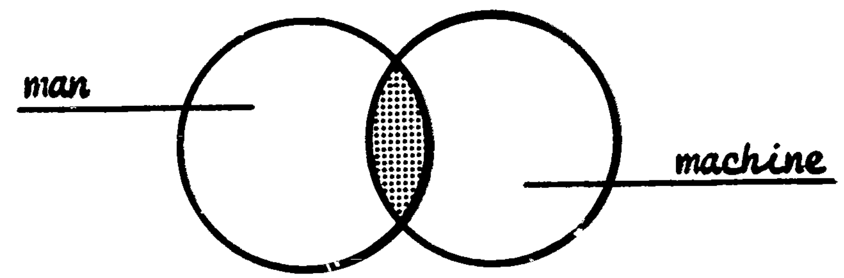
- As a paragon of rationality, the machine cannot begin to approach the annoying -- but pleasant and stimulating -- irrationality of man.

- There are great gaps between what the computer theoretically can do, and what it is able to do. The "state-of-the-art" may be such that no way of telling the machine what to do, or how to do it, has yet been developed.

This would be particularly true in architecture and planning where extensive uses -- and hence markets for technological improvements -- have not been developed.

These past paragraphs have served to illustrate a major point: BOTH MAN AND MACHINE HAVE STRONG POINTS. Possessing the ability to do the mechanical work of 100,000 men at once, the machine can be of great help for certain tasks, however, it lacks far too much to ever replace its inventor.

What is suggested is that there can be -- and there should be -- a natural partnership between man and machine. Perhaps the biologists have a better word for it: SYMBIOSIS, or the living



together of two dissimilar organisms for mutual advantage. The man and machine, in proper combination, can augment and complement each other, perhaps to the point of violating an old axiom: the whole can be greater than the sum of its parts.

The assessment of "place" for the computer in the architectural profession must become an in-depth study of this symbiosis. It must become a study of ways and means for man and machine, in partnership, to attack the problems in communication that face the profession today.

And this study must be genuine. Those involved must be careful not to fall into what Christopher Alexander calls the trap of "seeking applications": "The question, how can the computer be applied to architecture is misguided, dangerours, and foolish." Mr. Alexander likens this superficial kind of search to that of a small boy wandering around the house with a hammer in his hand, looking for ways to apply it. For the child, he suggests, the world of tools is more fascinating than the world in which the tools can be used. Will we fall into this trap?

Probably the best way to avoid it is to keep in mind the symbiosis of man and machine. Where are extra advantages to be gained from the combination?... and where are the results meaningless? Where are projects being undertaken to improve communication? .... and where are they being undertaken just to "play with the tool"?

In putting forth this concept of misguided application, Alexander has exposed one of many dangers that await men who misunderstand the machine or the man-machine symbiosis. There are more.

- The danger of DISTORTION. Not all aspects of problems, particularly architectural ones, are codable. Since the machine can only deal with the codable parts, there is the ever-present danger of distorting the problem to emphasize these aspects just to use the computer to solve it.

- The danger of INSIGNIFICANT ACCURACY. In designing a handball court, is it necessary to know the circumference of the ball to four decimal places? In laying out a radiology unit, is it necessary to know the average number of steps taken by a doctor in one day to the same four decimals? Every time we flirt with a device capable of such accuracy, we are tempted to use it, fooling ourselves into thinking it significant.

- The danger of BLIND BELIEF. Because a machine is big, expensive, and designed by some very smart people, there is no reason why it cannot be wrong. It is only as good as the man or men feeding it information and telling it what to do with this information.

- The danger of AWE or OMNIPOTENCE. The machine cannot do everything. Which brings us back to the beginning of this Part 2: before determining the "place" of the computer and its associated technology in the architectural profession, it is necessary to know something about it.

3 / status 1966

The next step in the search for the "place" of computer technology in the architectural profession is to examine what has been done and where we are in 1966.

There are probably four prime factors contributing to the status of computer use in architecture or any other field:

- NEED -- the existence of genuine need.
- ATTITUDE -- the reaction of the profession.
- HARDWARE -- the sophistication of machinery to handle the need.
- SOFTWARE -- the amount of thought and effort given to making the machinery usable to those needing it.

An examination of current computer use in the fields of architecture and planning reveals many important points, particularly in light of the four factors just listed:

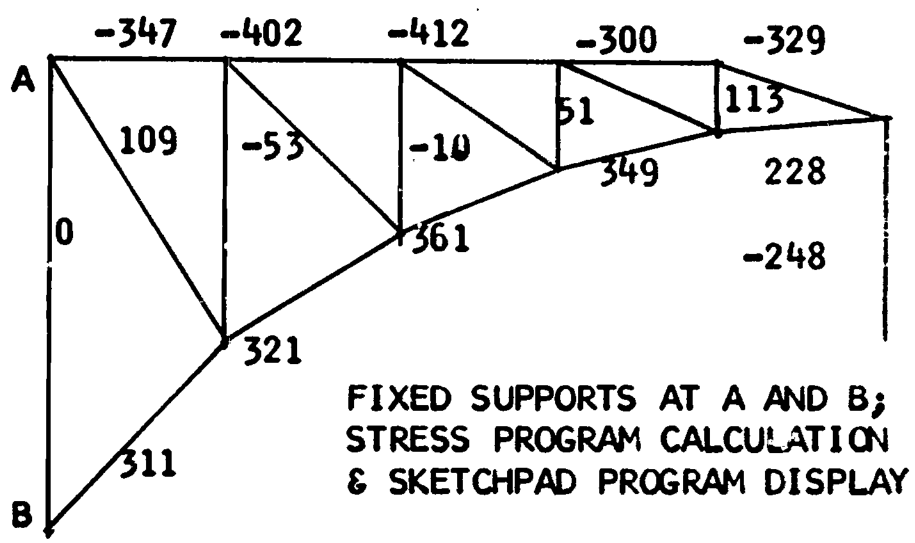
- Needs have yet to be defined in any detail.

- The attitude of the profession toward investigating the needs and the roles runs the gamut from real zeal to strong objection. Many are scared, most are totally uninformed.

- Since the market is not an active one, hardware has not been sophisticated to meet the unique demands of architects. Most uses utilize hardware developed to meet engineering needs.

- Advances in software (programs, instructions, etc.) are being made slowly and in line with the market demand.

It is easy to see that these four factors are greatly interdependent. They explain why computers will not overtake the profession all at once. They also explain why a hard look at the "place" of the computer in the architectural profession is needed now: if progress in hardware and software begin to move ahead of the need and the attitude, it will be too late. The directions will have been set by others -- the architect will not have had a chance.



FIXED SUPPORTS AT A AND B;
STRESS PROGRAM CALCULATION
& SKETCHPAD PROGRAM DISPLAY

In these last years of the 1960s, computer technology has found a real foothold in only a few specialized corners of the profession. Even though these "niches" are small, they are important:

- ENGINEERING APPLICATIONS
- JOB CONTROL AND MANAGEMENT
- SPECIFICATION WRITING
- FUNCTIONAL ANALYSIS

ENGINEERING APPLICATIONS. Several architectural and consulting firms have begun to use computer-based approaches and systems in some engineering areas. These include,

- Structural analysis -- study of optimum bay sizing, spacing and depth variations, comparison of systems. Done by simulating the proposed structural system under expected loads. Changes in loading or in structural system can be evaluated immediately.

- Structural design -- given structural configurations and loads, these programs (such as the MIT-developed STRESS program) can compute and plot stresses in each member.

- Special structural analysis -- such as computing effects on structures of complicated forces (wind, earthquake, etc.).

- <u>Site Engineering</u> -- computation of complicated areas, cuts and fills, elevations, earth moving for roads, drainage, etc. Most of these programs are designed to increase speed and accuracy of calculation.

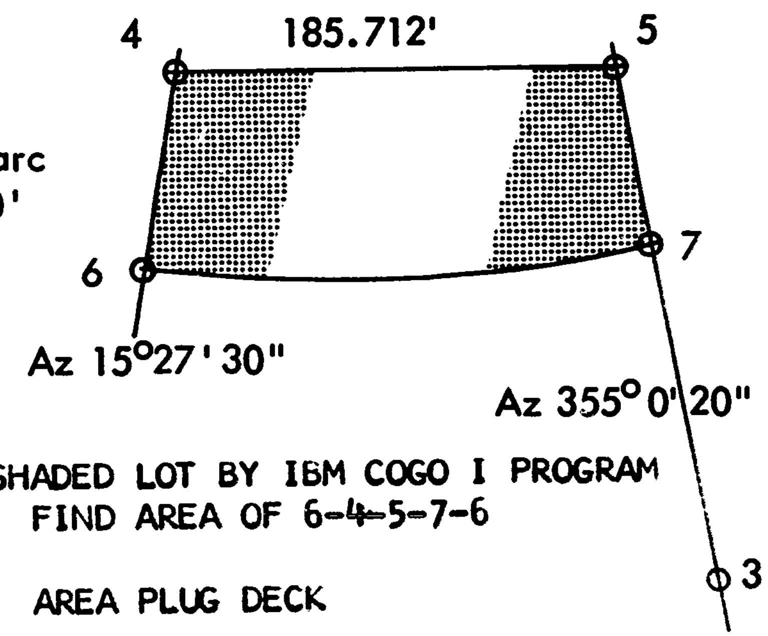
- <u>Heating and cooling analysis</u> -- some programs that are underway attempt to bring all the complex factors that go into mechanical design together into a workable package. A Westinghouse effort, for example, seeks to simulate the climatic and artificial factors contributing to heating or cooling a building, drawing from this analysis requirements for the building's heating and cooling system.

Most of these engineering uses have resulted from the development of small programs that can be used for many instances but in a limited area (such as the computation of stresses, but not moments or deflections). Eventually, these programs will be tied together into large, integrated packages that can greatly contribute to building design.

The use of the computer in areas of engineering is no accident:

- Most of these areas require a great deal of routine calculation. Design economies are not always attained because of the need to go through much calculation every time something new is tried.

radius of arc
= 725.000'

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AREA     6-4-5-7-6
11069.329 SQ FT    .25411682 ACRE
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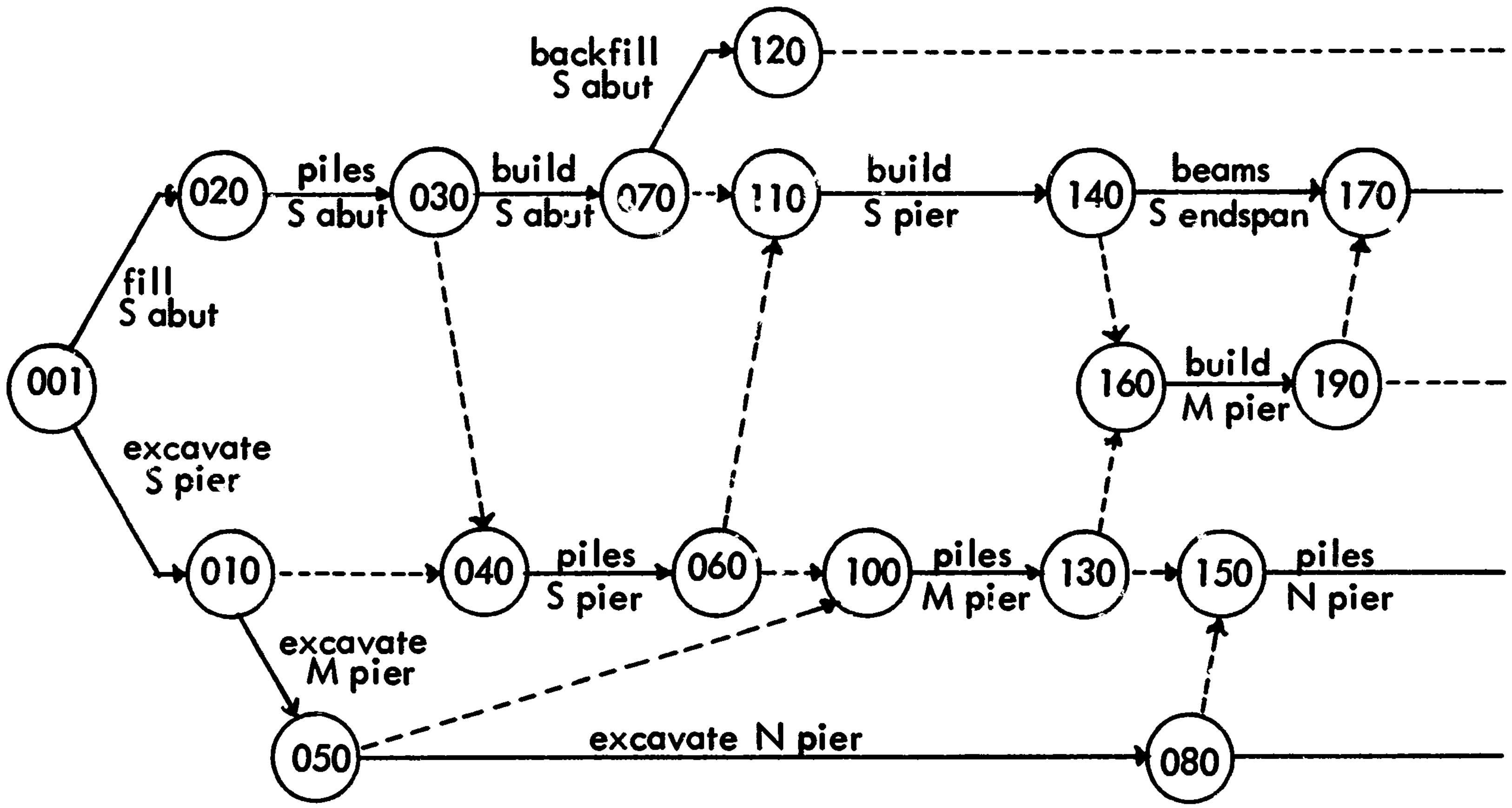
- Programming is not particularly difficult, and available hardware can be used.

- It is not necessary for the engineer to have continuous access to the machine. He can formulate problems and wait for answers; following his "results" from the computer, he will want to analyze them and propose changes before running the problem again. For this reason, the hardware does not have to be right in his office.

- Existing office procedures are not disrupted greatly.



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001	020	FILL SOUTH ABUTMENT	5.0	13SEP65	13SEP65	17SEP65	17SEP65	.0
080	180	FILL NORTH ABUTMENT	5.0	21SEP65	13DEC65	27SEP65	17DEC65	59.0
070	120	BACKFILL SOUTH ABUTMENT	5.0	3NOV65	28JAN65	9NOV65	3FEB66	62.0
230	280	BACKFILL NORTH ABUTMENT	5.0	2FEB66	15FEB66	8FEB66	21FEB66	9.0
001	010	EXCAVATE SOUTH PIER	2.0	13SEP65	26OCT65	14SEP66	27OCT65	31.0
010	050	EXCAVATE MIDDLE PIER	2.0	15SEP65	1NOV65	16SEP65	2NOV65	33.0
050	080	EXCAVATE NORTH PIER	2.0	17SEP65	7DEC65	20SEP65	8DEC65	57.0
020	030	PILES SOUTH ABUTMENT	12.0	20SEP65	20SEP65	5OCT65	5OCT65	.0
040	060	PILES SOUTH PIER	4.0	6OCT65	28OCT65	11OCT65	2NOV65	16.0
100	130	PILES MIDDLE PIER	15.0	12OCT65	3NOV65	1NOV65	23NOV65	16.0
150	180	PILES NORTH PIER	4.0	2NOV65	9DEC65	5NOV65	14DEC65	27.0

JOB CONTROL AND MANAGEMENT. Many architects have been specifying CPM and other network scheduling approaches for contractors since these methods were introduced a few years ago. Realizing that they have many of the same scheduling and manpower problems right in their own offices, architects are just beginning to apply some of the same thinking at home. These control methods include:

- Overall job scheduling -- use of Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) methods of network planning to schedule deadlines, determine manpower needs, and co-ordinate consultants and engineers. These methods do not necessarily require the sophistication of the computer.

- Financial planning -- budgeting, analysis of expenditures, co-ordination of commissions, etc.

- Office Routine -- accounting, payroll, billing, and other fiscal routine.

SPECIFICATIONS. Recognizing that specifications are less original writing and more assemblage of existing information, some architects are writing sets of "master" specifications, punching them into data cards, and selecting the necessary data cards for each project. Placing the data cards in a high-speed printer allows the printer to print them out, in pre-arranged format, on multi-lith or spirit process masters.

This approach does not require the use of the entire computer system (only punch and printer) and saves much of the repetition inherent in putting together specifications.

Using a computer program, however, allows the architect the opportunity to easily "edit" and re-assemble his specification for each job.

FUNCTIONAL ANALYSIS. The ability of the computer to digest a large amount of information, apply it to a specific problem, and then simulate results is already being applied in the area of functional analysis. A hospital ward, for example, can be subjected to the volume and type of traffic it will receive -- before the design is formalized -- allowing changes to be made and their effects evaluated. This simulation concept is being applied (in research work and in proprietary programs) to such diverse situations as supermarkets, elevator systems, and hospital operations.

Certainly the value of being able to record what has already happened in existing facilities can not be disregarded as a planning tool. Computer-based utilization studies, for instance, are playing significant roles in campus planning across the country.

OTHER CURRENT USES: There are several pioneer uses of computers in other aspects of practice. These are not at all widespread, however, and will be considered along with other possibilities in the next Part.

This discussion of current uses proves that the "place" of the computer in the practice of architecture has yet to be ascertained, but the pattern of acceptance is already beginning to evolve. Some needs have been recognized, some architects and engineers have accepted the use of the computer in meeting them, and manufacturers (in tandem with research groups) have moved to provide the necessary hardware and software.

4 / the future

In view of the communications problems facing the profession of architecture and planning, computers have only begun to play any kind of role in solving them. Rather than a close analysis of these present uses, the real "meat" of any discussion lies in the future -- what is being done to develop the technology, and what roles can it play in the years to come?

This consideration of future roles does not fall into the realm of idle daydreaming. Times move too quickly. Even though it is unrealistic to expect each of the possibilities to be realized in the next few years -- or even the next ten years -- there is little doubt that many of them will come to pass in time. It is up to the architectural profession to investigate them, and to give direction in the effort to develop them.

The investigations have been started; but, unfortunately, on the narrowest of fronts.

There has been a certain amount of research and development at the university level, and M.I.T. has to be listed as the pioneer in the field. There, great strides in developing engineering programs (such as STRESS, and ICES), have been coupled with the formulation of SKETCHPAD, the first real means of graphic communication with the computer. Other work at colleges such as Iowa State, University of California, University of Michigan, Penn State and the University of Pennsylvania have made smaller, but still significant, contributions.

In addition to university research, the hardware manufacturers and private systems analysis firms (such as California's System Development

Corporation) are looking into computers and their uses in a wide variety of fields.

The architectural profession, as a whole, has done very little. The AIA's Task Force on Automated Information, and its recently completed Analysis-Systems-Computers project, undertaken at Penn State, represent the bulk of its effort to date.

From the standpoint of the practitioner, probably the most significant research is being done in some of the larger offices in the country. Firms like Skidmore, Owings and Merrill, and Caudill, Rowlett and Scott -- each with the interest and the ability for undertaking efforts such as these -- have begun to use computer techniques for both economic and engineering analysis. Nolen, Swinburne Associates has given a great deal of thought to network planning and scheduling. These are the kind of efforts that are noticed by the rest of the profession; as they grow in scope and number, so will the "place" of the computer in the profession.

On the next few pages is a listing of some of the proposed uses and possibilities for computer technology in the profession. It is far from complete, but it represents the ideas of many who have done some thinking and projecting on the issue. It is not terribly specific in character; it is not meant to be. Rather than a specific inventory for others to follow or copy, it is intended to express the range of things that may be done with the new tools.

1 / PROGRAMMING

Utilization studies (past, present, future)
Functional analysis
Special facility type analysis (such as complicated lecture hall spaces)
Long-term planning
Optimum building size for economical use and return
General economic feasibility studies

2 / SITE ANALYSIS

Location of building in relation to needs, future trends, services, access, etc.
Siting of buildings
Analysis of population trends, neighborhood development, effect of new roads, etc.
General data organization and display

3 / BUILDING DESIGN

Analysis and ordering of the many variables that go into building design ("complete" design approach as suggested by Alexander and others)
Retrieval of pertinent information on structures, materials, equipment, climate and other "design factors"
Retrieval of information on similar solutions
Code and regulation check
Dimensional co-ordination, modular checks
Perspectives and views

4 / CIVIL AND STRUCTURAL DESIGN

Systems analysis and selection, including simulation of loading, optimum spans, required sizes, rough quantities, costing, optimum bay sizes
Systems design, including stress computation, member selection and sizing, length calculations, reinforcing design
Loading simulation to determine effects of changing loading patterns
Earthquake force simulation
Wind and lateral force simulation
Indeterminate analysis
Settlement and deflection analysis
Subsoil and earth bearing analysis; profiles
Cut-and-fill and earthwork calculations
Pavement and retaining wall design
Calculation of complicated areas, volumes

5 / ENVIRONMENTAL AND EQUIPMENT

Heating-cooling load analysis
HV A/C systems comparison
Optimum zone sizing
Mechanical system component sizing and selection
Plumbing sizing and selection
Electric load demand analysis, simulation of circuits for efficiency, wire and equipment sizing
Sewage and disposal system sizing

Equipment schedules, sizing, networks, demands on electric system, specification
Integrated components for environment

6 / SPECIFICATION OF NEEDS

Computerized specifications, general conditions, performance proceedures, etc.
Analysis of performance-bid proposals
Materials comparison on substitutions
Automated working drawings, drafting, fabrication, and shop drawings
Integration of standard details
Drawing check and dimensional correlation
Production of schedules, quantity surveys, lists for ordering materials, etc.

CITY AND REGIONAL PLANNING

Collection, organizing, and display of many kinds of planning data for use in city and regional planning studies
Simulation of population changes, new roads, industries, etc. for planning
Zoning
Simulation of existing and proposed traffic conditions for regional planning studies
Highway, railway, etc. location
Interchange location and design
Density and speed of traffic, present by analysis, future by simulation
Design and operation of traffic controls

1 / OFFICE MANAGEMENT

Financial and accounting routine, payroll, Posting, billing, etc.
Budgeting, expense analysis, and planning
Simulation of office operation for planning

2 / JOB CONTROL

Scheduling and balancing by CPM, PERT
Time and cost analysis
Filming or taping of work in progress for inefficiencies that can be corrected
Filming or taping of tests conducted at site

3 / CONTRACT ADMINISTRATION

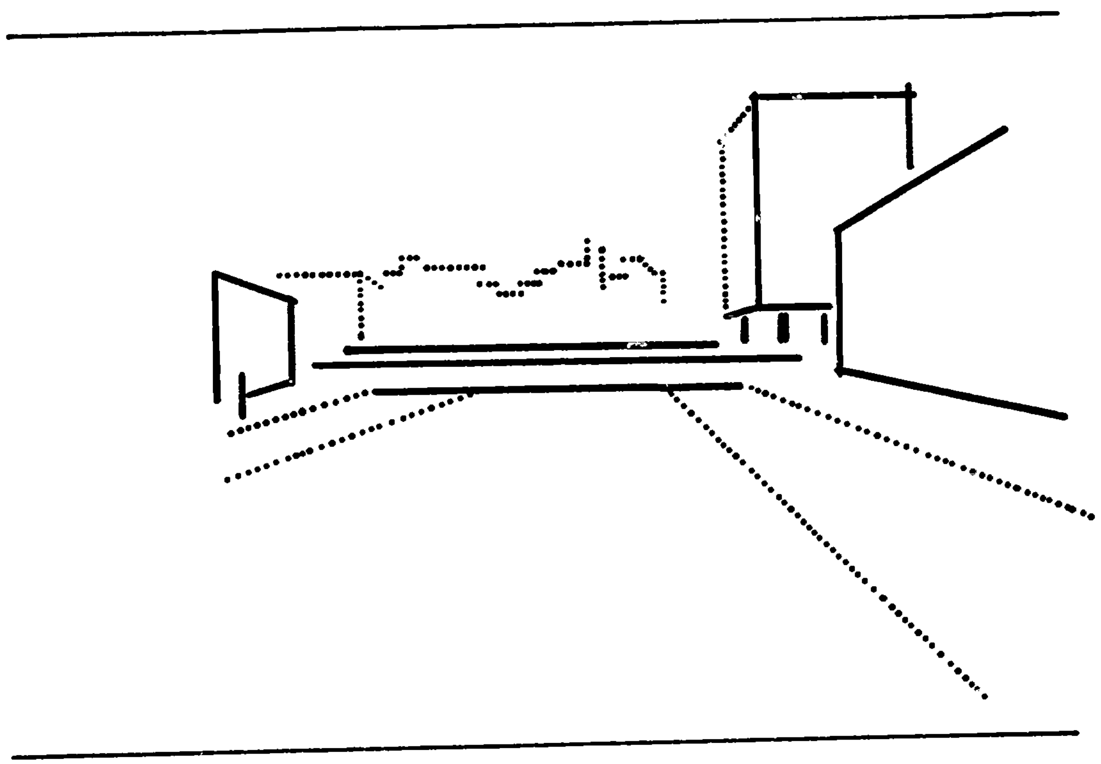
Contractor and manufacturer scheduling
Requisition analysis and handling
Disseminating results of field meetings
Constant revision of drawings through change orders; final "as-built" drawings

4 / INFORMATION HANDLING

Retrieval of pertinent information on products, projects, research, etc. when needed

5 / COSTING

Comparisons for design purposes
Estimates, quantity surveys, factor analysis
Ultimate, maintenance, long-term analysis



PROGRAMMING. As facility types become more and more involved, there are possibilities for computer simulation of what happens in them. (Souder and Clark have already tried this for complicated hospital systems). Other supporting data for programming, such as utilization factors, and long-term planning projections, can also be generated and organized for use by computer methods.

SITE ANALYSIS. Siting and location of buildings involves many complicated and interrelated factors, particularly in larger problems. While computers cannot make siting decisions, they can be used to organize data for ready use by the architect or planner.

BUILDING DESIGN. The role of computer technology in building design is harder to define. In all probability, computer graphics and computer drawing of perspective views at a moment's notice will give the designer greater lattitude in design, and provide him with immediate feedback after making a decision. Also, computers can be used to retrieve information pertinent to the problem, such code provisions, characteristics of materials, planning standards, and so on.

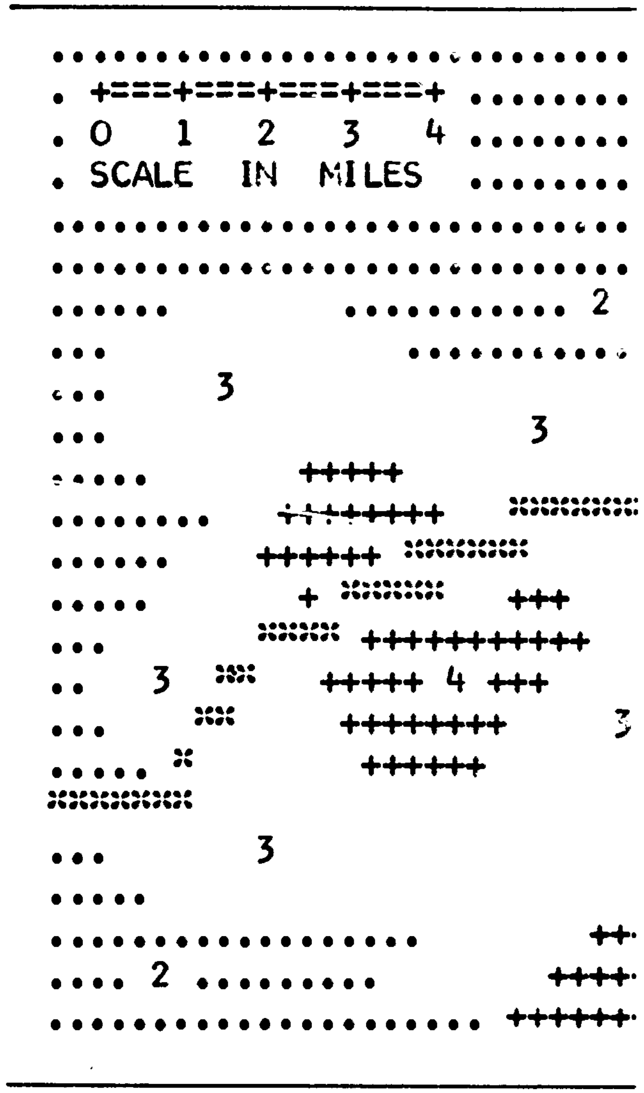
Some theoreticians, such as Christopher Alexander, propose bolder and more fundamental uses for the technology. Approaching architectural design as a

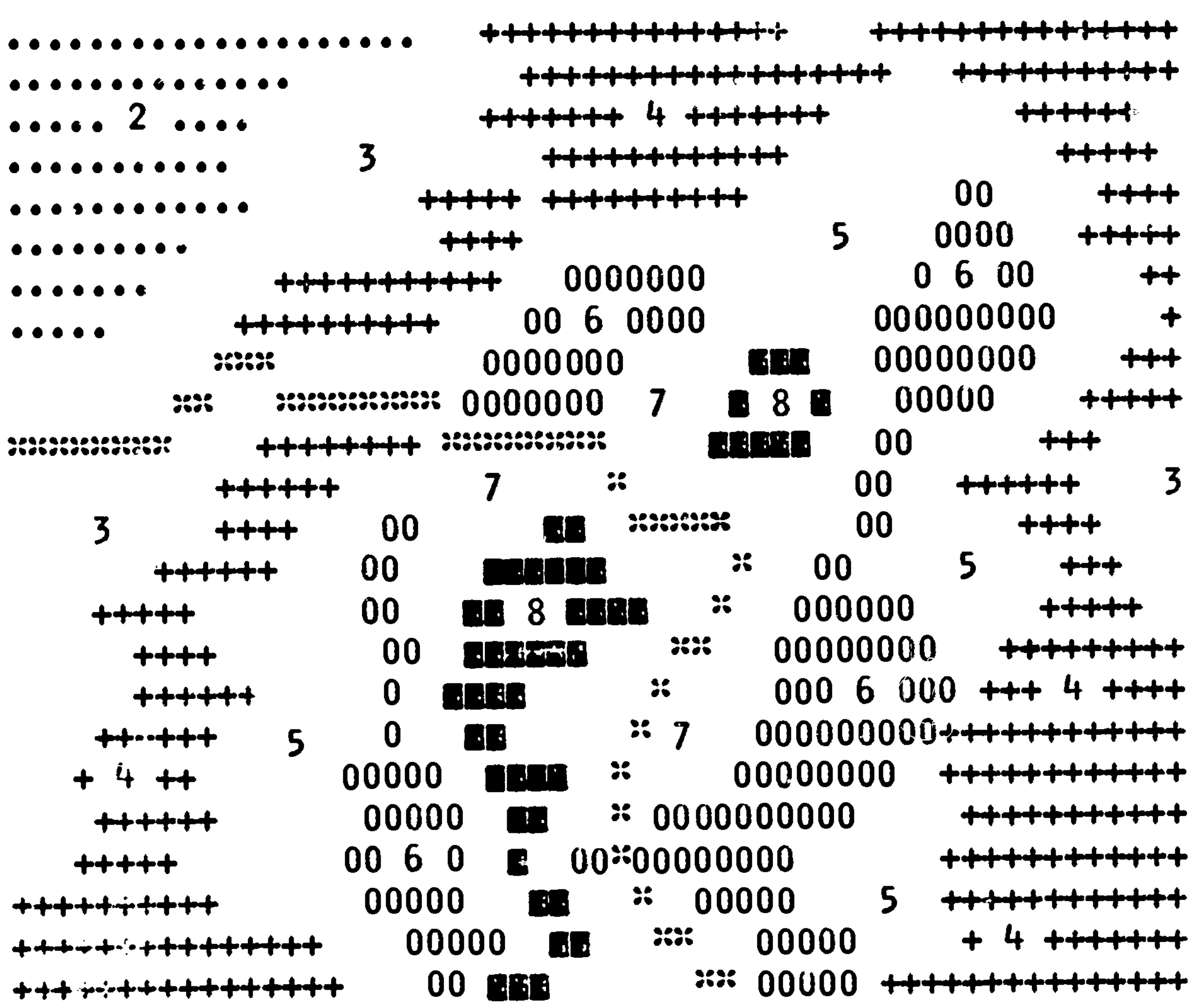
process with some rational aspects, Alexander and others feel that the rationale can be described and analyzed. To this end, codable design factors are determined, placed in natural "sets" and "subsets" and organized in ways that architects can readily handle. Already Alexander has graphically superimposed some 26 variables in the design of an interchange, drawing from his analysis an "ideal" location for the highway and access roads.

The most likely conclusion, at this time, is that design will become a most forceful example of man-machine symbiosis: the man putting together ideas and concepts, and making decisions, with continuous "support" from the computer in the form of retrieved information, data, standards, perspective drawings, and so forth.

ENGINEERING. The possibilities in the engineering areas are already seen -- the task is one of not only developing them, but of integrating them into a more logical whole. This may include analysis of building "systems" (integrated structural, mechanical, and even finish components). Whole new construction systems and approaches to the building process may be speeded through use of the technology.

SPECIFICATION OF NEEDS. There are great possibilities for eliminating much of the repetitiveness of writing specifications and producing working drawings. Advances have already been made in specifications, and automatic graphic plotting devices -- capable of turning out drawings from stored information -- are being sophisticated. Eventually these automated drawings may be extended to the making of shop and fabrication drawings, materials order lists, and production of schedules for equipment, hardware, finishes, etc. Final "as-built" drawings can be produced in the same way by feeding the machine changes.





MEDIAN INCOME - FAMILIES (IN DOLLARS)
LEVELS RANGE FROM 8 (HIGHEST) TO 1.

MANCHESTER AREA

AFTER SYNAGRAPHIC MAPPING AT HARVARD UNIVERSITY

PLANNING. The aspect of the computer that makes it most useful to planners is its ability to digest, organize, and display large volumes of raw data. The machine can also undertake the painstaking tasks of relating data with unequal bases -- such as number of crimes (recorded for each precinct) per capita (recorded by census tract). By simulating the conditions in a city or in a neighborhood, the machine can record -- and possibly display -- what happens to them when the planner varies the parameters.

By the same reasoning, conditions on a traffic interchange can eventually be simulated during various times of day, and under various traffic conditions; analysis of speeds and accident rates can eventually lead to safer and more efficient interchanges. Programs are also being developed that determine best possible highway routes, terrain analysis, and other aspects of highway design and route location.

OFFICE MANAGEMENT. The possibilities for taking over the endless routine of running the architect's office have already been mentioned. As the complexity of his business increases, and as fee structures remain unchanged, architects will be looking more and more to this kind of assistance.

JOB CONTROL. The use of CPM and PERT scheduling and resource balancing techniques will continue to grow as the practicioner recognizes that he must utilize his valuable resources as effectively as possible. Other aspects of communications technology, such as recording work in progress for improving detailing, supervision of construction, and watching tests from remote locations are other possibilities.

CONTRACT ADMINISTRATION. The routine of contract administration, from preparation of documents, to contractor scheduling, to budgeting and requisitions, to handling changes in the field, are possibilities for the technology. By using some automated devices for keeping track of this, not only will the job be done more accurately, but everyone will know what is going on at the same time. Some of the most bothersome of all communication problems -- those arising among all the agents on the site -- can be countered in this way.

INFORMATION CONTROL. The whole process of handling (or mishandling!) information, both within the profession and with other industries or professions, needs revising. The architect and the contractor just cannot keep up with the innovations of the manufacturer; feedback on new products from contractor to manufacturer is just as ineffective. One possibility for improved communication is through computerized shop drawings, materials lists, and specifications. Further developments in the areas of product literature and information, test results, characteristics of materials, and research documentation all are necessary.

COSTING. One great reason for lack of public confidence in architects is their inability to effectively handle the problem of costs. Estimates often run far afield, and it takes days to assess the effect of design decisions on the cost of the building. Once input methods are sophisticated, computer technology may be able to provide part of the answer. The machine could undertake quantity surveys, materials pricing, labor costs, giving the architect an objective "base" price to which he would have to add for local conditions. For this reason, machine-estimates may not be perfect, but they can give the architect "something to go on." Simulation techniques will also allow the computer to undertake long-term, ultimate, and maintenance cost analyses.

Another possibility in the area of costs is a computer - based cost "intelligence" system, tabulating anticipated projects in a geographic area, producing bid calendars, and developing projections based on history and trends. This kind of information would be most helpful to owners, architects and contractors in their long- and short-range planning efforts.

What has been presented so far is a list of individual possibilities, each a package of its own, and only loosely related to the whole. Many question that the technology will ever play this kind of role in the practice of architecture; they feel that there will be a thread of man-machine symbiosis that will wind through the project from beginning to end. This is briefly illustrated by the diagrams on the next pages.

overall building program for client; including determination of facility types, numbers, renovation possibilities, utilization factors and long-range planning

functional analysis of facility type

preliminary cost estimates based on similar facilities, cost indexes, etc.

economic feasibility of building under consideration; optimum size, number of floors, etc.

site selection based on several factors; determination of effects on neighborhoods, business, employees, etc. if a certain site is selected

PRELIMINARY ANALYSIS

call-up of research and historical information on similar problems, similar facilities, similar materials and structural systems

call-up of pertinent information on standards, codes, functional relationships, etc. to answer specific design questions.

first cost estimate, based on proposed design solution

use of systems and subsystems approaches to analyze design variables.

use of SKETCHPAD or other graphic devices to make quick line perspectives, elevations, etc. for design and rendering.

SCHEMATIC DESIGN

subsoil analysis and generation of earth profiles for foundation and earthwork design

cut-and-fill balancing, grading of site, route optimization of drives, etc.

cost estimates based on decisions to date

structural analysis and load simulation to select basic system; structural computation of stresses and selection of members, connections and reinforcing

quantity survey of all materials and equipment; basis for final objective cost analysis

computerized specifications

automated working drawings, preparation of shop and fabrication sketches, layouts, cutouts, etc.

check and dimensional coordination of all drawings and specifications

final objective cost analysis, quantity surveys, etc.

materials and finishes selection and specification

plumbing and waste system design

criteria for equipment and aid in selection

heating and cooling analysis based on building needs, orientation; design criteria for mechanical systems; aid in selection of components

bid check, analysis, and satisfaction of all performance requirements

requisition and payment handling; preparation of field reports and drawing revisions for change orders

construction scheduling

punch-listing and provision of final, "as-built" drawings

PHYSICAL SOLUTION

This is not to suggest that some giant macro-program, capable of handling every piece of information that may be encountered from the initial programming to the final punch-listing, should be the answer. Instead, it suggests that as man proceeds through the design and construction process, he may eventually be supported at every turn by the machine, by its ability to call-up information he needs, to organize that information into a form he needs to make a decision, and to simulate what will happen if he goes through with his decision. When this technology is not providing this direct kind of support, it can be handling his routine office and field operations. The man-machine symbiosis, and the technology that makes it possible, will become an integral part of the process.

It may not happen this way. At this point it seems to be a logical direction.

5 / the demands

As we have seen, the potential of the computer technology is immeasurable. It can -- and will, in time -- solve many of the communications problems faced by the profession. It can -- and will -- improve design and construction by bringing more information and experience to bear on a problem. It can -- and will -- make changes in office practice and job management that will allow architects to practice more effectively and with greater efficiency.

The technology has a deeper potential, though: that of inexorably changing the profession as it is assimilated into it. These changes can take several directions. More importantly, it is possible that the profession itself will not be in control of them. These aspects of the new technology bear not only the deepest thought, but the most immediate action.

First of all, the computer can have a great deal to say about the way the architect will practice. It can allow him to create a general, comprehensive practice that is now impossible, or it can reinforce the specialization so characteristic of the profession today.

As a means of bringing a great deal of information to the architect, and as a means of improving communicative links to other aspects of the building industry, computers can put the architect into the role of the master builder, the general overseer with responsibility for the complete job. This is the role that the A.I.A. and many others envision for him. He cannot do this now, for the process is just too complex for one man to keep track of. The computer does have the potential to change this.

Conversely, the technology has the power -- depending on how it is used -- to reinforce the specialization and fragmentation seen in today's practice. By giving engineers their computers, designers their computers, contractors their computers, and by improving communication between these, the technology can accomplish the exact opposite of the above: a series of independent, but interconnected, practitioners each working on his portion of the problem.

The computer has the potential for changing the entire complexion of office practice. As more repetitive tasks are eliminated, the structure of the office -- and the types of people required to staff it -- will change too.

Depending on how it is used, the technology does have the potential to eliminate -- yes, eliminate -- the architect as we know him. The tool may become powerful enough to "produce" buildings and cities in the hands of persons not trained as architects. Already we have seen the beginning of this: where are the architects when space capsules are designed? where are the architects on the research teams developing "complete environments" for space travel? where are the architects in many of the large city and regional planning efforts now in progress in this country?

Just because something is possible does not mean that it will happen....but just because the architectural profession may frown on the trends, does not mean that they will be reversed, either.

There is no question but that the technology will dictate change. As manufacturers and service bureaus see new roles and new uses for the technology in architecture and planning, they will not hesitate to develop them. As entrepreneurs, and others with titles we cannot even envision as yet, see the possibilities for producing environment with computer assistance, they will not hesitate to step in and do it.

What this all boils down to, then, is one question: where does the architectural profession stand? in other words, is it optimistic enough to hope that the computer will reinforce rather than diminish its role as the maker of environment?

Most who have thought about the issue feel that such optimism is not warranted. If the architect is at all interested in his future, he must be willing to take the leadership role, to carefully map out the roles of man and machine in the creation of environment. Once the leadership role is taken, the manufacturers and the service people will follow with the hardware and software necessary to fulfill the roles specified by architect and planner.

The path is clear, then. At this point the burden of responsibility lies clearly and squarely on the shoulders of the architect and the planner. They must attack the problem on the broadest of fronts:

- There must be an increased effort to make the architect and planner aware of developments and their implications. This responsibility rests with the architectural schools, the professional associations, and the communications media. It is tantamount to taking any kind of leadership role.

- The profession, as a whole and as a group of individuals, must step up research and development efforts in determining the "place" of the computer in practice. More theoretical research must be done in schools -- preferably architectural schools -- and more development and refinement work must be done in the field.

- Architects, and particularly those in education, must look forward to the professional practice of years to come. Without some ideas on where the profession is heading, it will be impossible to assess the roles of computer technology in helping it get there.

- After settling on roles for the computer, criteria -- demands -- must be established for manufacturers to follow in providing hardware and software.

- Finally, limitation as well as advantages must be kept in mind. Architects and planners must avoid, in their zealousness, the danger of SEEKING APPLICATIONS, the danger of DISTORTION, the danger of INSIGNIFICANT ACCURACY, the danger of BLIND BELIEF, and the danger of AWE.

But before we worry about the dangers of over-excitement, let us work up the excitement to begin with . . . .

. . . . THE NEXT MOVE IS OURS!

appendix

There seems to be a great aura of mysticism about the computer -- what it is, how it works, and how material must be"prepared" for its use. Of course, there are good reasons for this: the science that produced the machine is itself so new to us that complete understanding is the province of a select group who have fostered and developed it.

This does not mean, though, that some overall concepts cannot be explained in simple terms. This Appendix is directed at the professional who wants to have a rough idea of what the computer is and what it does.

The first few pages are devoted to going through the process that is necessary to get a problem ready for running on the computer -- a process perhaps known to us through the vague term, "programming". The remaining pages are devoted to a discussion of the machines themselves.

a PREPARING A PROBLEM FOR COMPUTER RUN

Any calculation you can devise has two integral parts: DATA and INSTRUCTIONS. The data are the raw material (facts, figures, pieces of information), and the instructions tell what must be done with them. When 2 is added to 2 to get 4, the "2"s are the data, and the "add" is the instruction.

This seems a little involved for such a simple calculation -- but it must be understood that a computer begins with a blank mind, and must be given two types of information to perform any calculation: data (facts) and instructions (what to do with the facts).

The DATA is the easy part. These are assembled by men, collated, and somehow "fed" into the computer. The means of feeding, and the kinds of conversions that the computer must make on the data to render it "palatable" are no real problem to the people that understand the machines.

The INSTRUCTIONS are a different story. Since computers can only perform a few fundamental math operations (add, subtract, multiply, divide, raise to power), the data analysis procedures must be broken down into thousands (sometimes millions) of single, precise instructions. The PROGRAM is this list of instructions; the program tells the computer what to do with the data.

Once an architect wants to use the services of a computer in a certain area or for a certain job, he must face the task of finding or preparing a program. Much simple programming for common tasks can be done by consultants and local programmers. The company which provides the hardware may provide programming assistance, too. Two alternatives are available on larger or more complicated jobs: finding an existing program and modifying it to meet demands, or contracting with a large programming or systems analysis firm. Of course, the first alternative is more desirable (and probably least expensive). Many stock programs, such as STRESS, already exist; the only problem is to track them down and to hope that they will be adequate for local conditions.

Even though the architect himself is not likely to get deeply involved in the programming process, he should be aware of the steps it entails, and how it is roughly approached. The steps include:

1. Problem Identification & Goal Description
2. Mathematical Description
3. Block Programming
4. Detailed Programming
5. Testing the Program

PROBLEM IDENTIFICATION

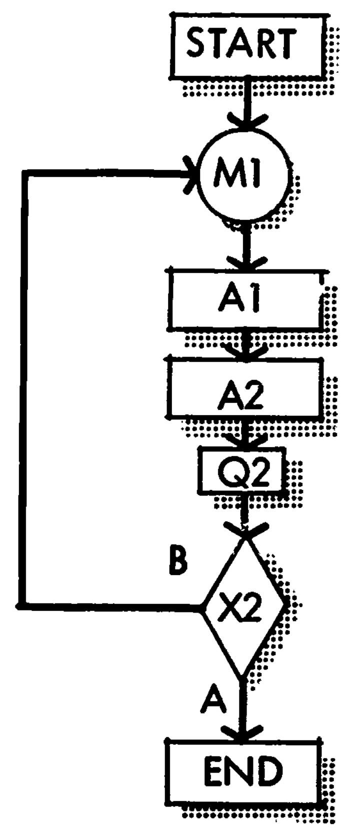
This first step in developing a new program entails a complete description of goals and an outline for a general approach to attaining these goals. While specifics are not important, it is important to realize what computers can and cannot do. This step demands complete familiarity with the problem at hand; it may be simple or it may take months or even many man-years.

MATHEMATICAL DESCRIPTION

The process must next be described mathematically and in steps that involve operations that the computer can do (addition, subtraction, multiplication, division, raising to power). This requires more specific knowledge about machine capabilities and an extensive background in mathematics and numerical analysis.

BLOCK PROGRAMMING

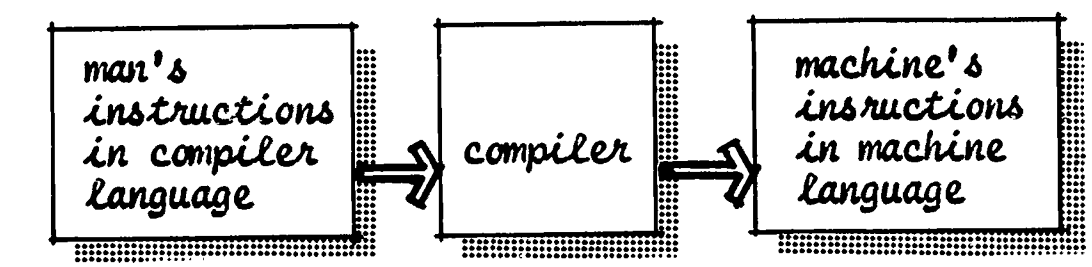
The preparation of a flow chart or logic diagram is the next -- and possibly the most important -- step in the process. This means breaking down the general method of solution into discrete steps. The steps are then connected by lines to give a diagram similar to the one shown on this page. In essence, this logic diagram shows that, after START, two activities are undertaken (A1 and A2). After these two are completed, there may be a wait (symbolized by a queue block, Q2). Then there is a decision required (symbolized by decision block X2) -- the process may be ready to end (Branch A), or it may have to be undertaken again (Branch B back up to merge point MI and through the process again). This is analogous to a student who starts, studies (A1), takes a test (A2), waits for results (Q2), and either passes (Split X2, Branch A), or fails and must repeat the process. (Split X2, Branch B).



DETAILED PROGRAMMING

The block diagram is a statement in lines and words; it must be made into something a machine can digest. The computer's basic language consists of many instructions (add, subtract, shift a number, etc.) and the problem-solving procedure must be translated into these terms.

Men can carry out the entire detail programming themselves. This is usually difficult, though, since the only language that most complex computers can understand directly is an extremely complicated one. Therefore, a common procedure is to have the computer do some of the translating itself through a compiler.



The COMPILER takes instructions that closely resemble the language of man, and performs the intermediate steps required to make it usable in the machine. Since compilers capable of taking instructions purely in everyday language have not as yet been developed, the programmer must learn a programming language. Such a language is FORTRAN; there are many. In using FORTRAN, the programmer can write instructions that look remarkably like everyday language, but which can be understood by the FORTRAN compiler and translated by it into machine language.

A typical FORTRAN program is presented on this page. This one looks particularly mathematical since it represents a set of instructions for computing a list of prime numbers from 1 to 1,000 -- a mathematical operation. The sample program, however, serves to illustrate the four types of statements found in computer programs:

1. OPERATIONAL, which tells the machine to perform a certain act (add, multiply, etc.)

2. INPUT/OUTPUT, which tells the machine to read a card, get some information from its memory, etc.

3. FLOW OF CONTROL, which gives instructions for sequencing, stopping, repeating, etc.

4. FORMAT AND COMMENT, which give information about the procedure and how to present results (Output).

```
    PRIME NUMBER PROBLEM
100 WRITE (6,8)
  8 FORMAT (52H FOLLOWING IS A LIST OF PRIME
    NUMBERS FROM 1 TO 1000, L9X, 1H1/19X, 1H3)
101 I = 5
  3 A = 1
102 A = SQRT (A)
103 J = A
104 DO 1 K=3, J, 2
105 L = 1/K
106 IF (L*K-1) 1, 2, 4
107 WRITE (6,5) I
  5 FORMAT (120)
  2 I = I + 2
108 IF (1000-I) 7, 4, 3
  4 WRITE (6,9)
  9 FORMAT (14H PROGRAM ERROR)
  7 WRITE (6,6)
  6 FORMAT (31H THIS IS THE END OF THE PROGRAM)
109 STOP
    END
```

TESTING THE PROGRAM

The last preliminary step is that of testing and "debugging" the program. There may be errors in logic, mathematics, or notation that must be ironed out before the program serves as an accurate list of instructions.

b THE ELECTRONIC COMPUTER

An electronic computer essentially consists of three parts:

1. INPUT UNITS.....which feed.....or introduce.....the data and the instructions into the machine.

2. CENTRAL PROCESSOR.....which controls processing, performs arithmetic, accumulates results, and maintains a quickly accessible memory.

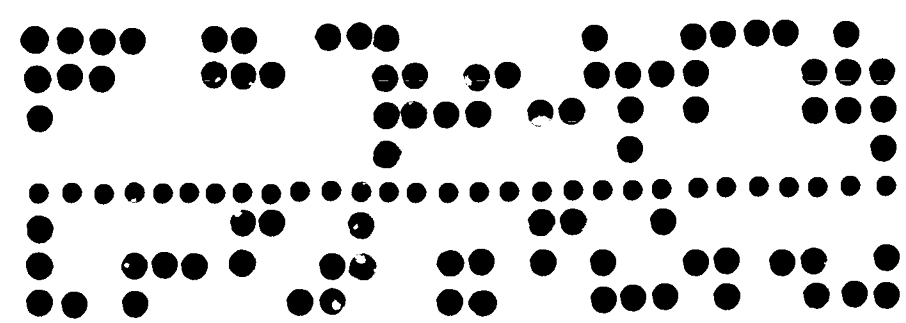
3. OUTPUT UNITS.....which serve two functions.....to create records, charts and reports for people to use.....or to create new media which can be reprocessed at a later date.

INPUT

The term "input" is used to describe the act of getting data and instructions into the computer. For the selection of steel beams, input might include a framing plan of the building, the load patterns, the steel beams (and their properties) available for use in the building, <u>and</u>, lest we forget, the program (or set of instructions) which tells the machine what to do with this information.

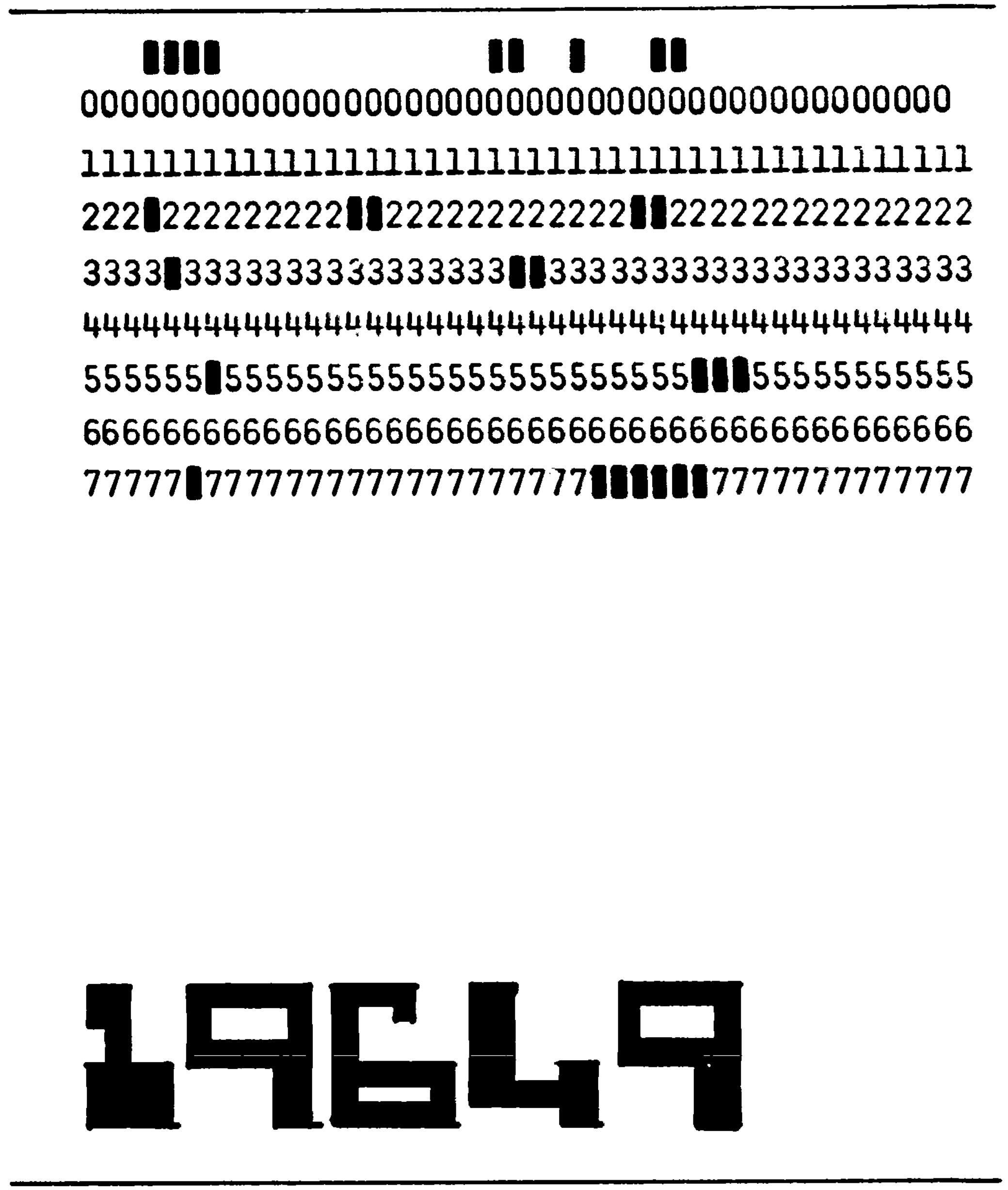
The computer requires that this data be "regimented" into some form, using some medium, that lends itself to automatic processing; the day is not here where we can just pick up a microphone and "talk" directly to the machine, "reading" data into it by voice. The "reading in" must be accomplished by other means, such as those listed in the following paragraphs.

PAPER TAPE. A common form of input is punched paper tape. By using a machine that looks something like a typewriter, information can be typed and punched into a paper tape. A Paper Tape Reader can then "read in" the punched information at rates up to 1,000 characters a second. The paper tape punching operation can be done ahead of computer run, saving the tape spools and "reading in" the information at the time of processing.



PUNCHED CARDS. Like paper tape, cards can be keypunched and later read into the computer via a High-Speed Card Reader. The Card Reader may be capable of handling 1,000 cards a minute, converting their punches into electrical impulses as it goes along. This information is entered into the machine's storage, and the cards can be saved for future use.

An advantage of the cards is that they are "unit" media -- one piece of information per card -- and can be "reshuffled" for future use, something that is hard to do with continuous paper tape.



MAGNETIC CHARACTER SCANNING. MICR (Magnetic Ink Character Recognition), developed by the banking profession along with the computer manufacturers, is known as the "common language" for banks. What happens is that the ink used in printing characters on checks can be given small charges of electricity. A computer-linked sorter "reads" these magnetic characters, not only sorting the documents, but entering their information into memory.

The magnetic-character sorter can also be used "off-line" -- not under direct supervision by the computer -- for straight sorting operations.

OPTICAL CHARACTER SCANNING. Reading devices have been developed that can recognize alphabetic

and numeric characters as long as they are given special shapes. The data are then transmitted into electrical impulses and placed in computer memory for processing.

The advantages are obvious: since both man and machine can read the characters without further "regimentation", an intermediate step has been eliminated. Efforts are now under way to devise scanners that will "recognize" a character no matter how awkwardly it is shaped, and it appears that progress is being made -- slowly, but surely!

LIGHT PEN AND OSCILLOSCOPE. A means of input currently being sophisticated should be of particular interest to architects: "writing" directly on a cathode-ray tube (or other electro-sensitive surface) with a special "pen" that activates material on the surface, changing it to an impulse that can be stored in computer memory. SKETCHPAD (see Text) uses this technique to get revisions into the machine.

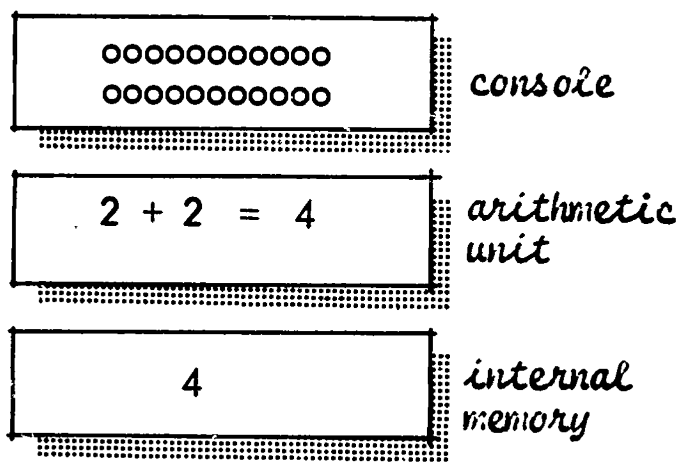
This is an "on-line" technique which is meant to be used to directly feed the computer while it is processing.

TYPEWRITER. Each of the proprietary computer systems utilizes some kind of typewriter through which the operator can directly communicate with the computer. It is not only used for routine console directions (start, stop), but can serve as a direct means of communication during processing. Routines requiring constant operator participation (such as programmed instruction by computer) usually use typewriter terminals -- which may be remote from the computer -- as input means.

THE PROCESSOR

The processor is the central unit of the system, and is made up of three parts:

1. A Console
2. An Arithmetic Unit
3. An Internal Memory



The Console

The console is the external control center of a computer and is used primarily to monitor the system. The panel is made up of a series of lights which serve as visible signals to the operator, and a series of buttons which enable the operator to give certain commands, such as the starting and stopping of processing.

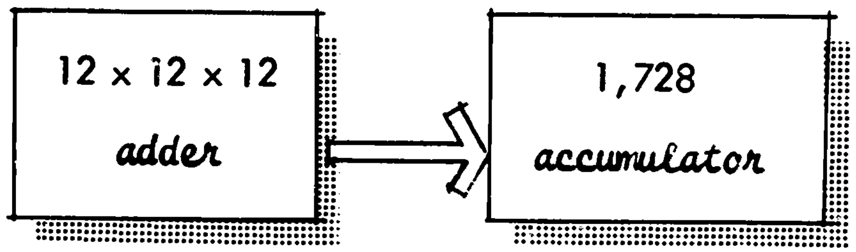
Also built into the console is an electric typewriter which serves as a means of communicating with the processor, and for the processor to communicate with the operator. Because of its internal speed, however, the computer does not rely upon the human operator to feed it data and to initiate its every command. As a result the control panel is used primarily to supervise, or to permit humans to communicate with, the various units which make up a total system.

Arithmetic Unit

This is the unit where the arithmetic functions are performed in the computer. Basically it consists of two sections: an adder, and an accumulator.

The ADDER is that portion of the arithmetic unit where the arithmetic (add, subtract, multiply, divide, raise to power) is actually performed.

The ACCUMULATOR is that portion of the arithmetic unit where the result (answer) is stored.



Internal Memory

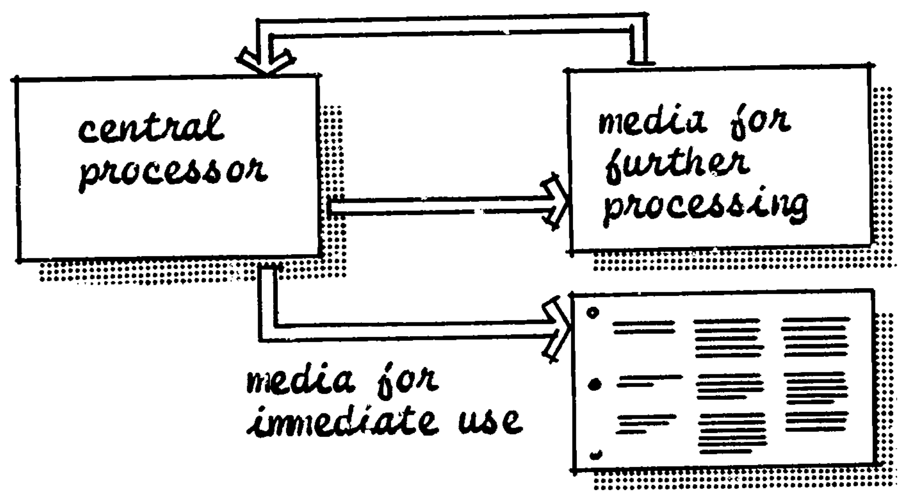
The internal memory of a computer can take any number of forms. It stores words, or basic "bits" of information, and the operations in storing and retrieving the information are necessarily complicated. It would seem senseless to present even the most rudimentary example at this point.

OUTPUT

The term OUTPUT is used to describe the act of extracting information from the central processing unit. This can be done for either of two reasons:

1. To get reports for people to use.
2. To create new media which can be stored in the machine and available for further processing.

Sometimes the output is in both forms. The various means for creating output are briefly discussed in the following paragraphs.



PRINTERS. High-speed printers can be utilized to print out results in report form -- either on standard printing paper or on special forms developed to fulfill specific needs. Compared to computing, printing is a rather slow operation, although some new models can print as many as 1,100 lines (132 characters long) per minute. Results can also be printed on multi- lith or spirit-process stencils for immediate duplicating if this is desired.

PLOTTERS. Various plotting units have been devised for printing out data in graphic form. At this date, these devices are rather slow but the ready value of graphic output for many needs is speeding their research and development.

TYPEWRITERS. Computers can activate "on-line" typewriters, either at the console or remote from the computer, as means of printing out information for immediate use.

PAPER TAPE. Paper tape can be punched as an output form, utilized at some later date for re-processing. A disadvantage of this approach is that the results are not in usable form for people to use; in many cases, however, this is not a requirement.

PUNCHED CARDS. Cards can be punched as an output form, sometimes at the rate of 250 cards a minute. These cards can not only be used for further processing, but are readable themselves since the information on them can be printed across the top as they are punched.

MAGNETIC TAPE. Probably the most common form of output designed for later processing is magnetic tape. Information can be read onto the tape, the tape spool stored either "on-line"with the computer if the data is needed right away,or in a tape storage library in the computer center with manual access.

This is an extremely popular means of output, since much information can be stored in a small space, and data can be read on and off the tape at high speeds.

C COMPUTER HARDWARE AND SYSTEMS

Except for the very first invention, there probably exists no one machine that can be called a complete computer. These machines are thoroughly componentized, and an installation is really a "system" of components put together to meet the specific needs of the owner or renter. The following paragraphs briefly present descriptions of many of these components; the chart on this page outlines the types of components available for just one computer system: the IBM 1401.

Units of the IBM 1401 System:

1401 Processing Unit (Models A,B,C,D,E,F)
1402 Card Read-Punch (Model 1)
1403 Printer (Models 1 and 2)
1404 Printer (Model 2)
1406 Storage Unit (Models 1, 2 and 3)
729 Magnetic Tape Unit (Models II, IV and V)
7330 Magnetic Tape Unit
1405 Disk Storage Unit (Models 1 and 2)
1407 Console Inquiry Station
1412 Magnetic Character Reader (Model 1)
1419 Magnetic Character Reader (Model 1)
1418 Optical Character Reader (Models 1 and 2)
1428 Alphameric Optical Reader
1009 Data Transmission Unit
1011 Paper Tape Reader
1012 Tape Punch

PROCESSING UNITS. The central processing unit is really the "computer", containing the adding and accumulating functions referred to above. The processing unit is monitored by a console and contains a memory unit.

STORAGE UNITS. Several proprietary storage units are available, but they usually break down into three generic types: core, magnetic drum, and magnetic disk.

INPUT/OUTPUT UNITS. These are described above and many include Card Punches and Readers, Tape Punches and Readers, Magnetic Character Sorter - Readers, Optical Scanners, Typewriters, etc. Those simply used to regiment data for computer use (such as Card Punches) are not used "on-line" at all. Other "off-line" uses include sorting by magnetic characters, using the printer to print-out information contained on punched cards, etc.

SPECIAL INPUT/OUTPUT UNITS. Remote typewriter terminals, tele-processing units, and graphic plotters are examples of special input/output devices which may be hooked "on-line" with the computer--be it in the same room or many miles away.

Of special interest to the architect are graphic consoles which are designed to display information visually. A light pen can then be used to modify what is presented, with the result going back into memory for later use. Many of these units have formalizing capabilities; that is, they will take wavy lines drawn by the operator and make them straight, or into perfect circles, and so on. Many of these involve writing on cathode-ray tubes, but newer models are more like flat glass plates and are easier to use. So far these communication units are expensive (a graphic console and a light pen might cost of to $10,000) but rapid development should bring costs down.

The chart on the next page was originally presented in Architectural and Engineering News in the March 1965 issue and is intended to show the range of hardware available. Of course, each system is tailored to individual needs by manufacturers and distributors.

MANUFACTURER and MODEL	work area (sq. ft.)	system price	monthly rental	input-output	power supply	visual display
Burroughs E-103	desk	$ 29,700	$ 875	1,3,4	220V	NO
Clary DE 60	8.4	20,000	525	1	115V	NO
Friden 6010		19,000+	650	1,3,4		
General Precision LGP-30	12	49,500	1,000	1,3,4	110V	NO
Monorobot XI	desk	24,000	700	1,3,4,7	850W	NO
Control Data 160A	90	90,000+	2,250+	1,2,3,4,5	115V	NO
Control Data G15	60	70,000	2,000	1,2,3,4	3.8KVA	NO
General Electric 215	400	375,000	6,500	1,2,3,4,5	10KV	NO
General Precision 4000	120	87,500	1,750	1,4	110V	NO
Honeywell 400	360	225,000	8,000	1,2,3,4,5	15KVA	NO
I B M 1620	100	95,000	2,000	1,3,4	230V	NO
I B M System 360/Model 50	1.7-15	133,000-5,500,000	2,700-115,000	1,2,3,5	8.3-72KVA	YES
N C R 390	247	62,000	1,300	1,3,4,6	230V	NO
Philco 1000	300	250,000	7,000	1,2,3,4,5		NO
R C A 301	400	271,000	5,500	1,2,3,4,5	19KVA	NO
R C A Spectra 70		192,000-864,000	4,000-18,000	1,2,3,4,5,6,7		YES
Scientific Data 910		73,000	2,190	1,2,3,4,5	7KW	NO
Univac 1050	800	350,000	7,250	2,3	10KVA	NO
Burroughs B 5000	1,000	790,000	13,000	1,2,3,4,5	29KVA	NO
Control Data 1604-A	600	1,750,000+	36,650	1,2,3,4,5		NO
General Electric 210	850	750,000	14,000	1,2,3,4	10KVA	NO
Honeywell 800 II	950	815,000	17,000+	1,2,3,4,5	30KVA	NO
I B M 7010		945,000	19,175	2,3,4,5	230V	YES
I B M 7090/7094		3,000,000	64,000+	2,3,4,5	36KVA	NO
Philco 210	1,200	2,000,000	28,000	1,2,3,4,5	24KVA	NO
R C A 3301	1,000	900,000	18,000+	1,2,3,4,5	23KVA	YES
Univac III	2,000	1,100,000	22,500	1,2,3,4,5	47KVA	NO

Input/Output: (1) Typewriter (2) Magnetic Tape (3) Punched Card (4) Paper Tape (5) Remote Station (6) Magnetic Strip (7) Magnetic Cards.

glossary

BINARY. A condition in which there are only two possible choices, such as on-off, plus-minus. A binary code developed for machines (using plus and minus charges) uses the digits 1 and 0 to represent all numbers and symbols.

Binary notation is not hard to learn. Remembering that it uses "2" as its base rather than "10" as we are used to, a look at this example should help:

BASE 10:		10^3		10^2		10^1		10^0			
or		1000		100		10		1			
1732	=	1000	+	700	+	30	+	2	=	1732 (base 10)
97	=	0	+	0	+	90	+	7	=	97 (base 10)

BASE 2:		2^3		2^2		2^1		2^0		
or		8		4		2		1		
1001	=	8	+	0	+	0	+	1	=	9 (base 10)
1111	=	8	+	4	+	2	+	1	=	15 (base 10)

BIT. A single character in a binary number. A unit of information capacity in a storage device. The number is derived from an acronym, Binary Digit.

COMPILE. To produce a language the machine can use (an extremely complex process) from a program. The part of the computer called the compiler takes the program and data inputs and translates them into its own language. Once programming languages and the appropriate compilers are evolved, the programmer has no interest in the machine's own language.

COMPUTER, ANALOG. A computer which measures variables by analogies. Physical conditions (such as temperature, pressure) are changed to electrical or mechanical quantities which can be

measured by the machine. The analog computer is a measuring device.

COMPUTER, DIGITAL. A computer which processes information by translating it into discrete numbers. It counts rather than measures.

COMPUTER, HYBRID. A computer having both analog and digital features.

CYBERNETICS. The field of technology which is involved in the study of the control and intercommunication of handling information, in machines and in the nervous systems of man and animals, in order to understand and improve communication.

FORTRAN. An example of a programming "language" which allows man to communicate with the computer without knowing the computer's internal language. The FORTRAN compiler converts the man-written symbols to computer machine "symbols".

HEURISTIC. Pertains to any process of obtaining solutions through trial - and - error methods. Many computer routines involving simulation and comparison with past experience are heuristic in nature. This is why many consider that computers can "learn".

INPUT. The act of introducing data and instructions into the computer.

INPUT MEDIA. The media used to introduce data and instructions into the computer. Includes punched paper tape, punched cards, magnetic character reading, typewriting, light pens, etc.

INSTRUCTION. A set of characters defining an operation which causes the computer to perform the operation. The instruction not only tells the computer what to do, but from where it must get any required data.

LOCATION. A storage position in the internal storage which can store one computer word. It is usually identified by an address which can locate the position of storage.

MEMORY. The internal storage of information in a computer system. Information may be stored here for short terms (after "reading-in" but before use) or for longer terms. There are many different approaches to storing information, including various types of magnetic tapes, disks, and drums.

MICROSECOND. Millionith of a second, 10^{-6} seconds.

MILLISECOND. Thousandth of a second, 10^{-3} seconds.

NANOSECOND. Thousandth of a millionith of a second, 10^{-9} seconds.

OFF-LINE. The use of computer system components (such as sorters, printers, etc.) not under direct supervision of the central console. If, for instance, information is generated in the processor, read on-to magnetic tape, and the information is later printed from the tape, the printer is being used "off-line".

ON-LINE. The use of computer system components under direct supervision of the console. Information is processed by the computer as rapidly as it is received or generated within it. Time-sharing terminals are "on-line".

PLOTTER. A device used in conjunction with a computer to plot points in the form of a graph.

PROGRAM. The complete plan for a solution of a problem. It includes the complete set of machine instructions and routines necessary to do the job.

READ-IN. To sense information contained in the source and transmit it to storage.

READ-OUT. To sense information contained in storage and transmit it as output.

ROUTINE, HEURISTIC. A routine by which the computer attacks a problem by trial-and-error, frequently involving the act of "learning".

SIMULATION. The representation of physical systems and phenomena by computers, models, or other means. Information enters the computer to represent the factors entering the real process, the computer produces information that represents the results of the real process, and the processing done by the computer represents the real process itself.

TELEPROCESSING. Communication between computer and remote terminal over standard telephone lines. Special sending and receiving units are needed to convert data into proper "pulses" to send over telephone lines.

TIME-SHARING. The use of a device for two or more purposes (or by two or more users) during the same time interval. Many computer systems are moving in this direction.

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